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P-3

RADIO CONTINUUM AND FAR-INFRARED EMISSION OF SPIRAL GALAXIES: IMPLICATIONS OF CORRELATIONS

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1. INTRODUCTION

We present a study extending the correlation seen between radio continuum and far-infrared emissions from spiral galaxies to a lower frequency of 408 MHz and also as a function of radio spectral index. The tight correlation seen between the two luminosities is then used to constrain several parameters governing the emissions such as the changes in star formation rate and mass function, frequency of supernovae that are parents of the interstellar electrons and factors governing synchrotron radio emission.

2. DATA

We make use of the 408 MHz catalog of Harnett (1982) and also the 1415 MHz sample of Hummel (1980) for galaxies common to both. The far-IR data are taken from IRAS SES Catalog wherever available, otherwise from IRAS PSC. Out of band correction is applied to get the total emission. In Figures 1 and 2 we show the plots of IR flux against radio flux at 408 and 1415 MHz, for two groupings of α , the radio spectral index. It is seen that at both frequencies there is an almost linear correlation fairly independent of α . We also find that the correlations are similar when derived luminosities are plotted. For both the 408 MHz and 1415 MHz samples, the exponent of correlation is close to unity and σ(RI), the dispersion in log L(R)/L(IR) is 0.21 to 0.29. The 6.3 cm and 2.8 cm data of Wunderlich et al. (1987) also give a linear dependence with $\sigma=0.2$. For this sample also the correlations are independent of radio spectral index; further, they are also independent of morphological type of the galaxies. It is interesting to note that the spectral index between 408 MHz and 6.3 cm and 2.8 cm as derived from the ratio of means of radio to IR fluxes is 0.64, same as that measured from multi-frequency measurements of radio galaxies from a given sample.

3. DISCUSSION

Luminosities in different bands are sensitive to star formation rate (SFR) averaged over different periods (stellar masses). For example, the blue luminosity samples SFR over a few billion years, whereas the far-IR luminosity is an average over a much shorter period. If the SFR and the initial mass function (IMF) were to remain invariant over time, there will be tight correlations between luminosities in different bands. The dispersion in the correlations are, therefore, indicators of changes in SFR/IMF. For our discussion we take the IRAS emission to be a reasonable measure of the warm dust luminosity arising from OB stars(Rengarajan & Iyengar, 1988). We also assume that the radio emission is due to synchrotron radiation from interstellar electrons injected from supernovae (SNe).The IR luminosity is computed by integration over the

product of IMF, the stellar life time, bolometric luminosity and an efficiency factor decreasing inversely as the squareroot of mass. The radio luminosity is proportional to the integrated number of stars above a mass threshold. We summarise the inferences that can then be drawn from the tightness of the correlations.

a) Gavazzi et al.(1986) find that $\sigma(BI) = \sigma(RB) = 0.35-0.4$ where B refers to the blue band. The much higher values of these dispersions as compared to the dispersion in the radio to IR emission implies that unlike the blue emission from longlived stars, both radio and far-IR emissions result from stars of similar masses viz. the high mass OB stars. Since progenitors of Type I SNe are longliving low mass stars as compared to the shortlived parents of Type II SNe, we infer that in spiral galaxies the latter are dominant. This is in accord with the observations of van den Bergh et al. (1987) on SNe frequency.

b) While the far-IR emission results from present day stars, the radio emitting electrons are stored in the galactic disc for about 10 million years; further the SNe are produced at the end of main sequence life-time. The dispersion $\sigma(RI)=0.2$ then implies that bursts of star formation changing the SFR by a factor > 2 and lasting about 10 million years must be rare.

c) The dispersion in the exponent of the IMF for different spiral galaxies corresponding to $\sigma(RI)=0.2$ is 0.3 for $M > 8 M$.

d) The tight correlation of L(R) and L(IR), its lack of dependence on morphological type and the small dispersion in the mean values of log L(IR)/L(B) for different morphological types imply that the dispersion in the mean frequency of SNe as a function of morphology is 30 percent only.

e) Unless there are correlated variations, the logarithmic dispersion in the confinement life time of electrons is 0.2 while the dispersion in the mean value of magnetic field for different galaxies is still lower, only 0.11.

f) The radio spectral index has a spread from 0.2 to 1.2. Can this arise from a single injected spectrum with a changing power law of the type seen in our Galaxy? The equlibrium electron spectrum can change due to changes in photon density arising from bursts of star formation. It is found that such effects cannot explain indices less than 0.6 unless the magnetic field is << a microgauss.

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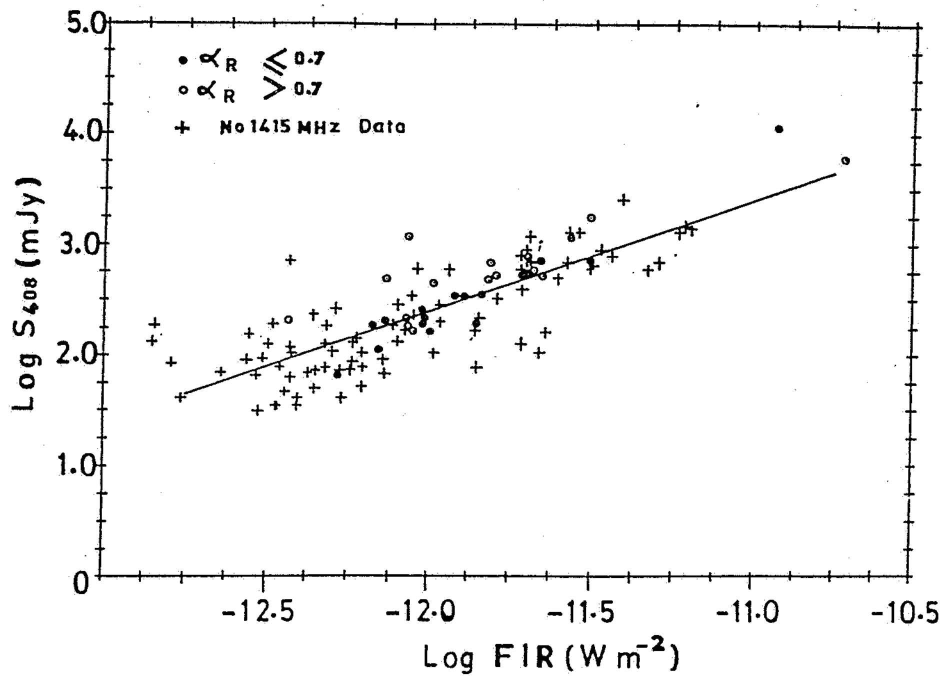

Figure 1

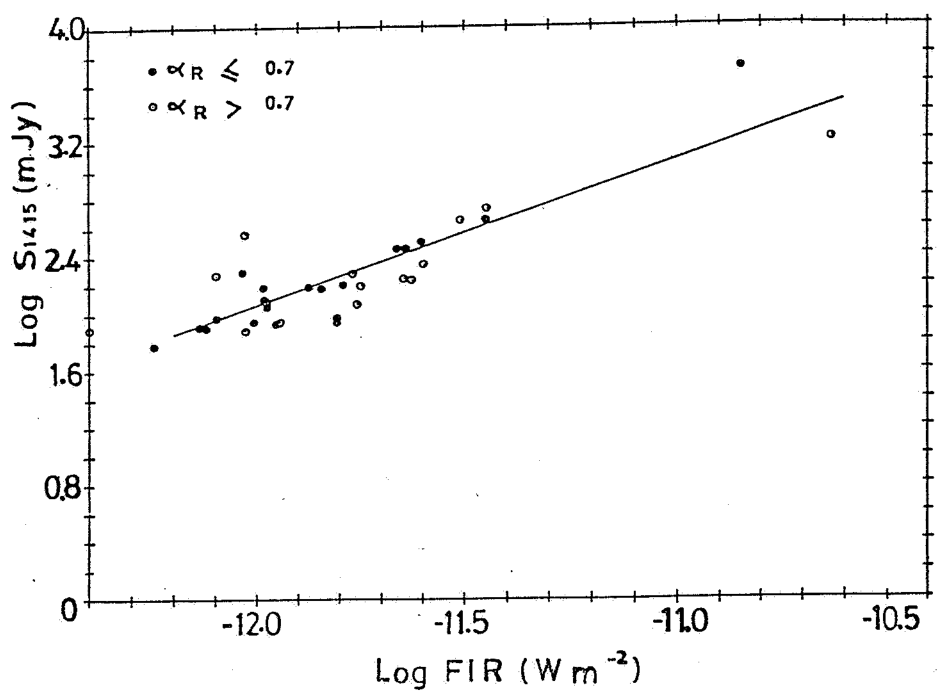

Figure 2